The Hobby-Eberly Telescope Chemical Abundances of Stars in the Halo (CASH) Project II. The Li-, r- and s-Enhanced Metal-Poor Giant HK-II 17435-00532


Abstract. We present the first detailed abundance analysis of the metal-poor giant HK-II 17435-00532. This star was observed as part of the University of Texas Long-Term Chemical Abundances of Stars in the Halo (CASH) Project. We find that this metal-poor ([Fe/H] = −2.2) star has an unusually high lithium abundance (log ε(Li) = +2.1), mild carbon ([C/Fe] = +0.7) and sodium ([Na/Fe] = +0.6) enhancement, as well as enhancement of both s-process ([Ba/Fe] = +0.8) and r-process ([Eu/Fe] = +0.5) material. The high Li abundance can be explained by self-enrichment through extra mixing mechanisms. If so, HK-II 17435-00532 is the most metal-poor star in which this short-lived phase of Li enrichment has been observed. The r- and s-process material was not produced in this star but was either present in the gas from which HK-II 17435-00532 formed or was transferred to it from a more massive binary companion. Despite the current non-detection of radial velocity variations (over a time span of ∼180 days), it is possible that HK-II 17435-00532 is in a long-period binary system, similar to other stars with both r and s enrichment.

1. Introduction

The story of early nucleosynthesis is written in the chemical compositions of the most metal-poor Galactic halo stars. Li, the only metal produced during the Big Bang, is often observed in unevolved metal-poor stars. Information on the primordial Li abundance can be inferred from, e.g., the Spite Plateau Li abundance that most metal-poor main-sequence stars tend to possess, log ε(Li) = 2.21 ± 0.09 (e.g., Charbonnel & Primas 2005), although the stellar result does not agree with the WMAP estimate of the primordial Li abundance, log ε(Li) = 2.64 ± 0.03 (Spergel et al. 2007). Some evolved stars, however, appear to have overabundances of Li—in contrast to the sparse galactic produc-

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Figure 1. Spectroscopic gravities are shown as a function of effective temperature for HK-II 17435-00532 and a sample of other evolved metal-poor stars from previous studies (Behr 2003; Cayrel et al. 2004; Preston et al. 2006). Three sets of $Y^2$ isochrones (Demarque et al. 2004) are displayed, along with a synthetic HB track (Cassisi et al. 2004).

The abundances are displayed in Figure 2. The Li abundance of $\log \varepsilon (\text{Li}) = 2.1$, is at odds with the evolutionary status of HK-II 17435-00532, i.e., it is far higher...
than expected from standard stellar evolution models. If this star is evolving up the red giant branch (RGB), it is located near the RGB luminosity bump, where extra mixing has been found to cause a short-lived phase of Li enrichment in more massive, metal-rich stars (Charbonnel & Balachandran 2000). See Figure 1. It is possible that the present Li abundance has already been reduced from its maximum abundance. If HK-II 17435-00532 is evolving through the RGB luminosity bump, it is the most metal-poor star for which an extra mixing mechanism has been shown to produce Li enrichment in the stellar envelope. Enrichment of Li is not expected to occur on the RHB or early-AGB; if HK-II 17435-00532 is on the RHB or early AGB, we are left to postulate that a previously-unidentified efficient extra mixing episode may be operating during this stage of evolution in low-mass, low-metallicity stars.

C and O are overabundant, [C/Fe] = +0.7 and [O/Fe] = +1.1. A comparison of HK-II 17435-00532 with the ten most metal-rich stars (−2.8 ≤ [Fe/H] ≤ −2.0) in the sample of McWilliam et al. (1995) suggests that all α- and Fe-peak abundances are consistent with “typical” metal-poor stars. The exception is Na, which is clearly enhanced, [Na/Fe] = +0.6. HK-II 17435-00532 exhibits overabundances of all n-capture elements, such as [Ba/Fe] = +0.86 and [Eu/Fe] = +0.48. These ratios suggest that HK-II 17435-00532 is enriched to some degree in both s- and r-process material, although neither the scaled-solar s- nor r-process abundances alone provide a satisfactory fit to the observed abundances. HK-II 17435-00532 has a similar n-capture abundance pattern compared with other r + s stars. The s and r nucleosynthesis reactions are not expected to operate in stars of sub-solar mass such as HK-II 17435-00532, so the n-capture elements must have been either present in the material from which the star formed or were transferred to it from an undetected binary companion.

Like HK-II 17435-00532, several other r + s stars also have enhanced Na abundances. The C, Na, and s-process enhancements can all be explained by assuming material was transferred to HK-II 17435-00532 from an undetected binary companion that passed through the AGB phase. In Figure 2 we display the measured [X/Fe] abundance ratios for 6 ≤ Z ≤ 63 in HK-II 17435-00532, along with the predicted abundance ratios (based on the FRANEC stellar evolution models; e.g., Straniero et al. 2003) from a binary mass transfer event. The best-fit is obtained with the a 1.5 M⊙ companion. We derive a dilution factor of 1.8 dex (i.e., a factor of ≈ 63), which means that one part of accreted material is present in the stellar envelope of HK-II 17435-00532 for every 63 parts of material originally present in the star. If we assume an initial [r/Fe] = +0.3 for this system, then only ~ 0.2 dex of Eu needs to be acquired from the s-process material of the AGB companion. In contrast to the Eu, which mostly reflects the initial composition of the ISM from which the system formed, the Ba (and other s-process species) was dominantly produced by the companion during its AGB phase.

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Figure 2. Predicted [X/Fe] ratios in HK-II 17435-00532 assuming pollution from a companion star that passed through the AGB phase. The initial mass of the AGB star is the primary variable between the different sets of abundance predictions, although changing the mass also changes the number of thermal pulses ("n") and necessitates altering the logarithmic dilution factor ("dil") and $^{13}$C pocket efficiency ("ST/"). The black curve reflects our best fit model.

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